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Abstract

This paper presents a model that links tax evasion, embezzlement, and the public good provision and suggests how they are interrelated. We characterize the conditions for three types of Nash equilibria: tax evasion, embezzlement, and efficient public good provision.

Keywords: Tax evasion, Embezzlement, Corruption, Audits, Sanctions, Public goods.

JEL Codes : H40, D83, D73

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1 Introduction

The theories of tax evasion and public good provision go back to several decades.[1,2] These are the two prominent factors affecting the income and expenditure side of a government budget. Moreover, it is often argued that tax evasion and corruption (such as embezzlement of public funds for private gain) are highly correlated.[3] Despite the obvious link between *tax evasion, embezzlement and public good provision*, there seem to have been an oversight in connecting these three different strands of literature. This paper attempts to remedy this neglect by providing a simple theoretical model connecting these three factors and providing insights on how they are inter-linked, thereby providing 'food for thought' to address these important economic issues.

Tax evasion is one of the central issues in public finance that affects developed, developing and under-developed economies. The initial study by Allingham and Sandmo (1972) analyses the individual taxpayer's decision on whether to evade tax or not, given that the tax is at a fixed rate on the declared income. The decision of a taxpayer is to choose an amount of undeclared income, in order to maximize her expected utility. The tax authority then randomly audits some taxpayers, and any tax-evading taxpayer is penalized. Since then the literature on tax evasion has developed in several directions, both theoretical as well as empirical.[4,5]

There is a vast literature on a public good provision, which focuses on efficient mechanisms of re-distributing public funds/goods and addressing the free-rider problem associated with it. Decentralized (or informal) sanctioning mechanism i.e. peer-punishments, is widely studied as a medium to improve compliance in case of public good games, see for instance, Fehr and Gächter (2000, 2002). Surprisingly, less attention is given to centralized (formal) sanctions as a means of encouraging individuals to contribute towards a public good.[6]

[1]The tax evasion literature started from Allingham and Sandmo (1972) and Yitzhaki (1974).

[2]The public good literature started from Samuelson (1954). See also Foley (1970), Green, Kohlberg, and Laffont (1976), Green and Laffont (1977), Groves and Ledyard (1977), among others.

[3]See Slemrod (2007), Casaburi and Troiano (2016), Litina and Palivos (2016).

[4]Yitzhaki (1974) provides the first extension of the seminal model of Allingham and Sandmo (1972). See Slemrod and Yitzhaki (2002) for a more detailed review of the theoretical models in the literature.

[5]See Slemrod (1985), and more recently Engström, Nordblom, Ohlsson, and Persson (2015), Rees-Jones (2017), among others.

[6]See Falkinger (1995) and Andreoni and Bergstrom (1996) for some initial theoretical work on formal sanctions. In addition, see Markussen, Putterman, and Tyran (2014) and Kamei, Putterman, and Tyran (2015) for experimental studies on the preference of individuals for formal vs informal sanction mechanisms.

The embezzlement of public funds by a public official is the simplest form of corruption, since these funds are generated from the taxes paid by citizens, and therefore they have to be re-distributed in the form of public goods. If there are no strict rules, a public official has all the incentives for appropriating funds for his personal gain.[7]

In this paper, we combine the important features of these three areas of literature on tax evasion, public good provision, and embezzlement.[8,9] We consider a simple model with two citizens and a governor. First, the citizens decide whether to pay or evade taxes. Then, Nature (or Internal Revenue Service in the USA) audits one of the citizens, at random, and in case of non-payment, the citizen is forced to pay the tax and an additional penalty. Third, the governor receives all citizens' taxes (after the audit) and decides how much of these public funds to use for the public good provision. Finally, after the governor's decision, citizens express their opinion whether he steals public funds or not. Citizens can punish the governor in case of embezzlement (for example, by filing a complaint) if they correctly guess total amount of public funds. This guessing is a proxy for voting in favour or against the governor.[10] We present our model in the form of a four-stage extensive form game.[11] Even with this very simple structure, we find some very interesting and intuitive results. We are able to discuss wide range of possibilities using four basic parameters of the model: a penalty parameter for the non-payment of taxes (z), a punishment parameter for the embezzlement of funds (b), a marginal per capita return from the public good (α), and a citizen penalty parameter for wrong guessing (c).

We analyse our four-stage extensive form game in several steps. First, we eliminate dominated actions. Then, we describe a normal form of this reduced game. Finally, we characterize Bayesian Nash equilibria of the game. It turns out that any strategy profile can be a Nash equilibrium for the right choice of parameters z, b, α, and c.

In order to select among different Nash equilibria, we assume that citizens care

[7]See some interesting theoretical and empirical studies by Ades and Di Tella (1999), Brollo, Nannicini, Perotti, and Tabellini (2013), Fisman, Schulz, and Vig (2014) discussing various incentives for politicians.

[8]See Cowell and Gordon (1988) for a related study linking literatures on tax evasion and public good provision.

[9]See Table 1 below for a snapshot of the relevant literature.

[10]See Reinikka and Svensson (2004), Azfar and Nelson (2007), Costas-Pérez, Solé-Ollé, and Sorribas-Navarro (2012), among others, for related experimental and empirical studies where some form of accountability (such as elections, public information dissemination, etc.) are used to discourage peculation of funds by public office.

[11]Our model has a flavor similar to that of yardstick competition. See Besley and Case (1995) for more details.

about their guesses, or $c > 0$. This natural assumption allows to refine our predictions. We get three types of Nash equilibria: tax evasion, embezzlement, and efficient public good provision. We show that whenever the penalty for the non-payment of taxes, z, is low, both citizens have an incentive to evade taxes. Similarly, when this penalty, z, is high enough and the punishment for stealing of public funds, b, is relatively low, at least one of the citizens pay taxes and the governor squanders public funds, when such an opportunity arises. We also find that for the efficient public good provision, i.e. a situation where both citizens pays taxes and the governor re-distributes the entire public fund, values of both parameters z and b need to be high, thereby demonstrating an inter-connection between them.

Table 1 below lists the relevant literature on tax evasion, embezzlement and public good provision, which our model attempts to unify. A few papers tried to link tax evasion either with public good provision or embezzlement (see Table 1 for details), but we believe that these three concepts are interrelated and should be studied together to improve policy implications. The outline of the paper is as follows. Section 2 describes our model and the reduced extensive form of the game. Section 3 presents the analysis of the model that includes the main results, a discussion of these results, and possible connections of these results with the existing literature. We conclude in Section 4.

Table 1: Literature on tax evasion, public good provision and embezzlement (corruption)

Public good provision	Tax Evasion	Embezzlement
Samuelson (1954)	Mirrlees (1971);	Peters and Welch (1980);
Foley (1970);	Allingham and Sandmo (1972);	Welch and Hibbing (1997);
Green, Kohlberg, and Laffont (1976);	Yitzhaki (1974);	Ades and Di Tella (1999);
Green and Laffont (1977);	Slemrod (1985);	Reinikka and Svensson (2004);
Groves and Ledyard (1977);	Cowell and Gordon (1988)*;	Azfar and Nelson (2007);
Smith (1980);	Alm, McClelland, and Schulze (1992);	Fisman and Miguel (2007);
Cowell and Gordon (1988)*;	Erard and Feinstein (1994);	Slemrod (2007)**;
Falkinger (1995);	Andreoni, Erard, and Feinstein (1998);	Ferraz and Finan (2008, 2011);
Andreoni and Bergstrom (1996);	Chander and Wilde (1998);	Barr, Lindelow, and Serneels (2009);
Chen and Plott (1996);	Slemrod and Yitzhaki (2002);	Costas-Pérez, Solé-Ollé, and Sorribas-Navarro (2012);
Falkinger, Fehr, Gächter, and Winter-Ember (2000);	Sandmo (2005);	Brollo, Nannicini, Perotti, and Tabellini (2013);
Fehr and Gächter (2000, 2002);	Slemrod (2007)**;	Fisman, Schulz, and Vig (2014);
Bracht, Figuieres, and Ratto (2008);	Bassetto and Phelan (2008);	Casaburi and Troiano (2016)**;
Uler (2011);	Kleven, Knudsen, Kreiner, Pedersen, and Saez (2011);	Litina and Palivos (2016)**;
Baldassarri and Grossman (2011, 2012);	Luttmer and Singhal (2014);	Alm, Martinez-Vazquez, and McClellan (2016);
Andreoni and Gee (2012);	DeBacker, Heim, and Tran (2015);	Bobonis, Cámara Fuertes, and Schwabe (2016);
Gibson, Tanner, and Wagner (2013);	Engström, Nordblom, Ohlsson, and Persson (2015);	Weitz-Shapiro and Winters (2017)
Markussen, Putterman, and Tyran (2014);	Casaburi and Troiano (2016)**;	
Hilbe, Traulsen, Röhl, and Milinski (2014);	Litina and Palivos (2016)**;	
DeBacker, Heim, and Tran (2015);	Artavanis, Morse, and Tsoutsoura (2016);	
Kamei, Putterman, and Tyran (2015)	Rees-Jones (2017)	
Robbett (2016);		
Grieco, Faillo, and Zarri (2017)		

*Literature connecting Tax evasion and Public good provision

**Literature connecting Tax evasion and Embezzlement

2 Model

We consider a four-stage extensive form game involving two citizens, C_1 and C_2, and a governor, G. The citizens need to decide whether or not to pay taxes, given that they may be audited and punished (in case of non payment). Nature selects one of the citizens at random to audit. The total tax collected goes into a public fund. After the tax payment decisions have been made by the citizens, the governor has to decide how much of the fund to use to provide a public good. Finally citizens voice their opinion about the governor's decision. We formally describe the four-stage game now.

Stage 1

Nature randomly selects to audit one of the two citizens with equal probability. Formally, the state of nature is $\Theta \in \{C_1, C_2\}$ where $\Pr\{\Theta = C_1\} = \Pr\{\Theta = C_2\} = \frac{1}{2}$ and citizen Θ is audited.

Stage 2

The choice of nature is not known to the citizens and $I^1_{i=1,2}$ denotes the information sets of citizen $C_{i=1,2}$ at this stage. $C_{i=1,2}$ has to decide whether to pay taxes, $t_i = 1$, or not, $t_i = 0$. We assume that the tax is 1 unit for each citizen and the total taxes go towards a public fund. Any non-payment implies tax evasion, i.e. 0 unit paid towards the public fund. After the citizens make their decisions, the information about the audit is revealed. If a non tax-paying citizen is audited, he will need to pay $1 + z$, where $z \geq 0$ is the sanction (penalty)[12] parameter.

Stage 3

Governor G receives the total public fund X, given by:

$$X = \begin{cases} 2, & if \quad \{\Theta = C_i\} \ \& \ \{t_{j \neq i} = 1\}, \\ 1, & if \quad \{\Theta = C_i\} \ \& \ \{t_{j \neq i} = 0\}. \end{cases} \tag{1}$$

If both citizens C_1 and C_2 pay taxes, the governor G will have $X = 2$ units, and it doesn't matter which citizen is audited. In a situation when both citizens C_1 and C_2 evade taxes (i.e. non-payment of taxes), one of them is audited and will have to

[12] We assume that the entire z collected goes to the independent tax authority, Nature, to help conduct audits, etc.

pay 1 unit (along with a sanction of z), implying a total contribution of $X = 1$ unit. If only one of the citizens evades taxes we have $X = 2$ units ($X = 1$ unit) when the tax-evading citizen is audited (tax-evading citizen is not audited). Formally, the governor G has two information sets : $\mathcal{I}_G = \{I_G^1, I_G^2\}$, where

$$I_G^1 = \{X = 1\} \text{ and } I_G^2 = \{X = 2\} \tag{2}$$

After G receives the public fund X, he decides how much of the public good to provide. When $X = 2$, the action set for G is $\{L, H\}$, where L (Low) and H (High) represent 1 and 2 units, respectively, of the public good provided by G. When $X = 1$, the governor G can only provide 1 unit, L, of the public good. We assume that G benefits from the public good provision too. We define an embezzling G as the governor who peculates one unit of public good when $X = 2$.

Stage 4

In the final stage of the game, we model a proxy for voting by incorporating a guessing mechanism where the citizens, C_1 and C_2, are required to guess whether total fund, X, is high (h) or low (l). We assume that wrong guess is costly and each citizen wants to guess correctly. Depending on which citizen was audited in Stage 1, one of them has more information about the possible X; we explain this below.

- If G plays H (provides 2 units of public good), each citizen has the dominant (guess) action h.
- If G plays L (provides 1 unit of public good), each citizen $C_{i=1,2}$ has three information sets: I_i^2, I_i^3, I_i^4, where

$$I_i^2 = \{(\Theta = C_i, t_{j\neq i} = 0, L), (\Theta = C_i, t_{j\neq i} = 1, L)\}, \tag{3}$$

$$I_i^3 = \{(\Theta = C_{j\neq i}, t_i = 1, L)\}, \tag{4}$$

and

$$I_i^4 = \{(\Theta = C_{j\neq i}, t_i = 0, L)\}. \tag{5}$$

At I_i^2, citizen C_i is not sure about the total public fund X and C_i's action set is $\{l, h\}$. At I_i^3, citizen C_i knows $X = 2$ and his dominant action is h. Similarly at I_i^4, citizen C_i knows $X = 1$ and his dominant action is l. For each citizen $C_{i=1,2}$, let g_i denote the guesses made by him:

$$g_i \in \{h, l\} \tag{6}$$

The guessing mechanism helps in representing a set-up where the citizens can punish (file a complaint, for example) against a governor who embezzles. The only situation this can happen is when $X = 2$ and the governor decides to provide 1 unit of the public good. Given that the governor embezzles, if the citizens correctly guess the total X, G's payoff will decrease by $b \geq 0$ for every correct guess, i.e. the governor loses confidence of his citizens. On the other hand, C_i's payoff will decrease by $c \geq 0$ for a wrong guess. We consider α as the marginal per capita return (or MPCR) of the public good, with $\alpha > 0$. The game concludes after Stage 4.

The payoff of $C_{i=1,2}$ is a function of:

$$\left[\Theta \in \{C_1, C_2\}; t_1, t_2 \in \{0, 1\}; \{L, H\}; g_i \in \{h, l\}\right].$$

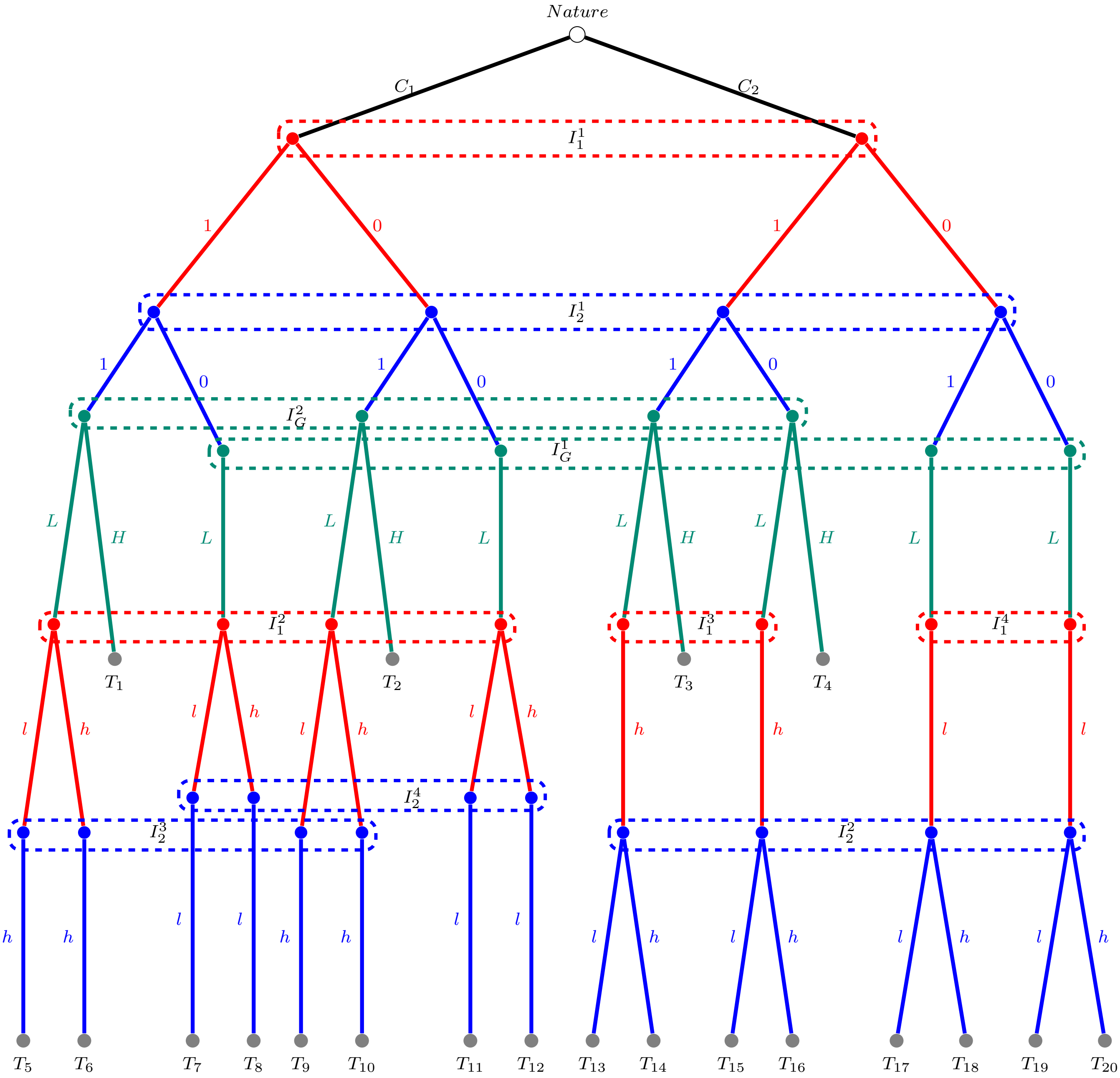
The payoff for G is a function of:

$$[\Theta \in \{C_1, C_2\}; t_1, t_2 \in \{0, 1\}; \{L, H\}; g_1, g_2 \in \{h, l\}].$$

Game Tree

We represent our extensive form game with a game tree. The nature starts the game by choosing which citizen C_1 or C_2 to audit (with probability $\frac{1}{2}$). C_1 and C_2 do not know who is being audited and they decide, simultaneously, whether to pay or evade taxes. The total taxes go towards a public fund (X). After citizens have made their moves, G receives X. G can not observe the actions of C_1 and C_2 from the previous stage and has two information sets: I_G^2 for $X = 2$ and I_G^1 for $X = 1$. At I_G^2 he has two actions, either provide 2 units (H) or provide 1 unit (L) of the public good; while at I_G^1 his only action is L. After G has made his decision, C_1 and C_2 will guess how much X was, which is the last stage of the game. When C_i is not sure about X he will be at information set I_i^2. At information set I_i^3(similarly, I_i^4), C_i is sure that $X = 2$ ($X = 1$), and thus has a dominant action of h (l). This gives us the reduced form of the game tree with 20 terminal nodes and the corresponding payoffs being summarized in Table 2.

Figure 1: Reduced extensive form of the game



	Information sets	Color
C_1	I_1^1, I_1^2, I_1^3, I_1^4	
C_2	I_2^1, I_2^2, I_2^3, I_2^4	
G	I_G^1, I_G^2	

Table 2: Table of Payoffs

Terminal nodes	C_1	C_2	G
T_1	$-1+2\alpha$	$-1+2\alpha$	2α
T_2	$-1-z+2\alpha$	$-1+2\alpha$	2α
T_3	$-1+2\alpha$	$-1+2\alpha$	2α
T_4	$-1+2\alpha$	$-1-z+2\alpha$	2α
T_5	$-1+\alpha-c$	$-1+\alpha$	$1+\alpha-b$
T_6	$-1+\alpha$	$-1+\alpha$	$1+\alpha-2b$
T_7	$-1+\alpha$	α	α
T_8	$-1+\alpha-c$	α	α
T_9	$-1-z+\alpha-c$	$-1+\alpha$	$1+\alpha-b$
T_{10}	$-1-z+\alpha$	$-1+\alpha$	$1+\alpha-2b$
T_{11}	$-1-z+\alpha$	α	α
T_{12}	$-1-z+\alpha-c$	α	α
T_{13}	$-1+\alpha$	$-1+\alpha-c$	$1+\alpha-b$
T_{14}	$-1+\alpha$	$-1+\alpha$	$1+\alpha-2b$
T_{15}	$-1+\alpha$	$-1-z+\alpha-c$	$1+\alpha-b$
T_{16}	$-1+\alpha$	$-1-z+\alpha$	$1+\alpha-2b$
T_{17}	α	$-1+\alpha$	α
T_{18}	α	$-1+\alpha-c$	α
T_{19}	α	$-1-z+\alpha$	α
T_{20}	α	$-1-z+\alpha-c$	α

3 Analysis of the model

A pure strategy for a citizen (or governor) specifies a complete plan of actions, i.e. an action for the citizen (or governor) at each information set. For each $i \in 1, 2$, the pure strategy set for citizen C_i consists of the Cartesian product $\{1, 0\} \times \{l, h\} \times \{l, h\} \times \{l, h\}$. Similarly, the pure strategy set for governor G is given by $\{L, H\} \times \{L\}$. Each citizen has 4 information sets with 2 actions at each information set. Therefore, each citizen has $2^4 = 16$ pure strategies. The pure strategy set of citizen $C_{i=1,2}$ is $S_i = \{1lll, 1llh, 1lhl, \ldots, 1hhh, 0lll, \ldots, 0hhh\}$.

At information sets I_i^3 and I_i^4, h and l are the dominant actions for $C_{i=1,2}$. Thus, we eliminate dominated strategies and consider only a "reduced" strategy set (with some abuse of notation) for citizen $C_{i=1,2}$: $\mathrm{S}_i' = \{1l, 1h, 0l, 0h\}$, where two actions in each strategy report choices at information sets $I_i^1$and I_i^2. The governor has only one action at information set I_G^1. Thus, with some abuse of notation, we denote the governor's reduced strategy set as $S_G' = \{L, H\}$. The following reduced normal form game $\mathcal{B}$ (see Table 3) summarizes the expected payoffs[13] for all the possible outcomes of the game.

[13] An example: A strategy profile such as $(1h, 0l, L)$ refers to citizen 1 playing $1h$, citizen 2 playing $0l$ and the governor G playing L. Given this, the expected payoffs are as follows:

$$E(u_{C_1}) = \frac{1}{2}(-1 + \alpha - c) + \frac{1}{2}(-1 + \alpha) = -1 + \alpha - \frac{1}{2}c$$

$$E(u_{C_2}) = \frac{1}{2}\alpha + \frac{1}{2}(-1 + \alpha - z - c) = -\frac{1}{2} + \alpha - \frac{1}{2}z - \frac{1}{2}c$$

$$E(u_G) = \frac{1}{2}\alpha + \frac{1}{2}(1 + \alpha - b) = \frac{1}{2} + \alpha - \frac{1}{2}b$$

Table 3: Reduced normal form game, $\mathcal{B}$

L				
	$1l$	$1h$	$0l$	$0h$
$1l$	$-1+\alpha-\frac{1}{2}c$ $-1+\alpha-\frac{1}{2}c$ $1+\alpha-b$	$-1+\alpha-\frac{1}{2}c$ $-1+\alpha$ $1+\alpha-\frac{3}{2}b$	$-1+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $\frac{1}{2}+\alpha-\frac{1}{2}b$	$-1+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha$ $\frac{1}{2}+\alpha-b$
$1h$	$-1+\alpha$ $-1+\alpha-\frac{1}{2}c$ $1+\alpha-\frac{3}{2}b$	$-1+\alpha$ $-1+\alpha$ $1+\alpha-2b$	$-1+\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $\frac{1}{2}+\alpha-\frac{1}{2}b$	$-1+\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\alpha$ $\frac{1}{2}+\alpha-b$
$0l$	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-1+\alpha$ $\frac{1}{2}+\alpha-\frac{1}{2}b$	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-1+\alpha-\frac{1}{2}c$ $\frac{1}{2}+\alpha-\frac{1}{2}b$	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha$ α	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ α
$0h$	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-1+\alpha$ $\frac{1}{2}+\alpha-b$	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-1+\alpha-\frac{1}{2}c$ $\frac{1}{2}+\alpha-b$	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-\frac{1}{2}+\alpha-\frac{1}{2}z$ α	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ α

H				
	$1l$	$1h$	$0l$	$0h$
$1l$	$-1+2\alpha$ $-1+2\alpha$ 2α	$-1+2\alpha$ $-1+2\alpha$ 2α	$-1+\frac{3}{2}\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$	$-1+\frac{3}{2}\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$
$1h$	$-1+2\alpha$ $-1+2\alpha$ 2α	$-1+2\alpha$ $-1+2\alpha$ 2α	$-1+\frac{3}{2}\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$	$-1+\frac{3}{2}\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$
$0l$	$-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $-1+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$	$-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $-1+\frac{3}{2}\alpha-\frac{1}{2}c$ $\frac{3}{2}\alpha$	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha$ α	$-\frac{1}{2}-\frac{1}{2}z+\alpha$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ α
$0h$	$-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $-1+\frac{3}{2}\alpha$ $\frac{3}{2}\alpha$	$-\frac{1}{2}-\frac{1}{2}z+\frac{3}{2}\alpha$ $-1+\frac{3}{2}\alpha-\frac{1}{2}c$ $\frac{3}{2}\alpha$	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\alpha$ α	$-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ $-\frac{1}{2}-\frac{1}{2}z+\alpha-\frac{1}{2}c$ α

We are ready to present our first result now.

Theorem 1. *For any strategy profile $s^* = (s_1, s_2, s_G)$, there exist parameters z, c, α, b such that s^* is a pure strategy Nash equilibrium (PSNE, henceforth) of the reduced normal form game $\mathcal{B}$, where $s_{i=1,2} \in \{1l, 1h, 0l, 0h\}$ and $s_G \in \{L, H\}$.*

The proof of Theorem 1 is relegated to the Appendix. We observe that any strategy profile in the reduced normal form game $\mathcal{B}$ can be a PSNE and Table 4 summarizes the corresponding conditions on the parameters z, c, b, α such that Theorem 1 holds true. Each cell in Table 4 provides the restrictions on the parameters such that the outcome corresponding to that particular cell (from Table 3) is a PSNE. For example, consider the outcome $(0h, 1h, H)$ in Table 3 where C_1 plays $0h$, C_2 plays $1h$ and G chooses to play H. From Table 4, it is easy to see that when $c = 0$, $z = 1 - \alpha$ and $b \geq \frac{1}{2}(1 - \alpha)$, $(0h, 1h, H)$ is a PSNE of the game. Our model provides an extremely rich setting which helps us describe any possible situation using four simple parameters. We are not aware of another model which obtains a similar result. Given the simplicity of our model and the amplitude of this result, it is possible to explain what conditions will result in a particular setting. For instance, we can provide specific restrictions on the parameters which will result in a particular scenario (such as the citizens evading taxes or the governor embezzling funds, etc.) to exist in a society.

Theorem 1 offers us a wide range of possibilities. We now want to restrict our discussion to some specific situations of economic interest and for the purpose of doing so we assume some restrictions on parameter c.

Table 4: Conditions on parameters

L				
	$1l$	$1h$	$0l$	$0h$
$1l$	$c = 0, z \geq 1$ $b \leq 1 - \alpha$	$c = 0, z \geq 1$ $b \leq \frac{2}{3}(1 - \alpha)$	$c = 0, z = 1$ $b \leq (1 - \alpha)$	$c \geq 0, z = 1$ $b \leq \frac{1}{2}(1 - \alpha)$
$1h$	$c = 0, z \geq 1$ $b \leq \frac{2}{3}(1 - \alpha)$	$c \geq 0, z \geq 1$ $b \leq \frac{1}{2}(1 - \alpha)$	$c = 0, z = 1$ $b \leq 1 - \alpha$	$c = 0, z = 1$ $b \leq \frac{1}{2}(1 - \alpha)$
$0l$	$c = 0, z = 1$ $b \leq 1 - \alpha$	$c = 0, z = 1$ $b \leq (1 - \alpha)$	$c \geq 0, z \leq 1$ —	$c = 0, z \leq 1$ —
$0h$	$c \geq 0, z = 1$ $b \leq \frac{1}{2}(1 - \alpha)$	$c = 0, z = 1$ $b \leq \frac{1}{2}(1 - \alpha)$	$c = 0, z \leq 1$ —	$c = 0, z \leq 1$ —

H				
	$1l$	$1h$	$0l$	$0h$
$1l$	$z \geq 1 - \alpha$ $b \geq 1 - \alpha$	$z \geq 1 - \alpha$ $b \geq \frac{2}{3}(1 - \alpha)$	$c \geq 0, z = 1 - \alpha$ $b \geq 1 - \alpha$	$c \geq 0, z = 1 - \alpha$ $b \geq \frac{1}{2}(1 - \alpha)$
$1h$	$z \geq 1 - \alpha$ $b \geq \frac{2}{3}(1 - \alpha)$	$z \geq 1 - \alpha$ $b \geq \frac{1}{2}(1 - \alpha)$	$c = 0, z = 1 - \alpha$ $b \geq 1 - \alpha$	$c = 0, z = 1 - \alpha$ $b \geq \frac{1}{2}(1 - a)$
$0l$	$c \geq 0, z = 1 - \alpha$ $b \geq 1 - \alpha$	$c = 0, z = 1 - \alpha$ $b \geq 1 - \alpha$	$c \geq 0, z \leq 1 - \alpha$ —	$c = 0, z \leq 1 - \alpha$ —
$0h$	$c \geq 0, z = 1 - \alpha$ $b \geq \frac{1}{2}(1 - \alpha)$	$c = 0, z = 1 - \alpha$ $b \geq \frac{1}{2}(1 - \alpha)$	$c = 0, z \leq 1 - \alpha$ —	$c = 0, z \leq 1 - \alpha$ —

3.1 $c > 0$

Assuming the citizens do care about the wrong guesses (i.e. $c > 0$), we discuss below few interesting outcomes/scenarios.

Example 1. Tax evasion: Assuming $z = \frac{1}{2}$, we have $(0l, 0l, L)$ as the PSNE of the reduced normal form game[14], where both citizens evade taxes and guess correctly that the governor had one unit for public good provision and the governor provides L level of public good. Proposition 1, below, generalizes this result.

Proposition 1. *If the punishment for tax evasion is relatively small, i.e.*

$$0 \leq z \leq 1 \tag{7}$$

there exists at least one pure-strategy (tax evasion) Nash equilibrium where both citizens evade taxes.

Given the condition in inequality (7), we have a second PS(tax evasion)NE profile $(0l, 0l, H)$, where both citizens evade taxes and guess correctly that the governor had one unit for public good provision, and the governor provides two units (H) in the information set, which is out of the equilibrium path. Our Proposition 1 is consistent with most of the literature: if the penalty on tax evasion is small, then each citizen has the dominant strategy to avoid paying taxes. The theoretical literature on tax evasion[15] goes back to Allingham and Sandmo (1972) and Yitzhaki (1974). These studies provide simple theoretical model where individual tax payers decide whether or not to evade taxes in the presence tax enforcement (i.e. random audits, penalties, etc.). There have been extensions to these two models in various contexts and Sandmo (2005) provide an extensive review on the literature on tax evasion.[16] A more recent study by Kleven, Knudsen, Kreiner, Pedersen, and Saez (2011) extends the model by Allingham and Sandmo (1972) and suggests that for self-reported income the empirical results are aligned with the theoretical model[17], i.e. tax evasion is substantial and is negatively related to an increase in penalties, probability of audit, etc. This result can also be connected to another stream of literature on sanctions

[14]See Tables 3 and 4 for details.

[15]The literature on optimal taxation starting from Mirrlees (1971), and more recently Chander and Wilde (1998) and Bassetto and Phelan (2008), among others, provide some insights towards tax enforcement techniques and their effects on tax evasion and avoidance.

[16]See also Andreoni, Erard, and Feinstein (1998) for a review describing the major theoretical and empirical findings in the tax compliance literature, focusing mainly on income tax compliance.

[17]See also Artavanis, Morse, and Tsoutsoura (2016) for a related study.

in case of public good games.[18] Baldassarri and Grossman (2012) conducted lab-in-the-field experiments to show that subjects significantly increase their contribution in the presence of centralized sanctioning mechanism.

Example 2. Embezzlement: Assuming $z = 2$ and $b = \frac{1}{4}$, we have $(1h, 1h, L)$ as the PSNE of the reduced normal form game[19], where both citizens pay their taxes and guess correctly that the governor had two units for public good provision and the governor provides L, i.e. the governor embezzles one unit of public good. We generalize this result formally in the proposition below.

Proposition 2. *If the punishment for tax evasion is high enough,*

$$z \geq 1$$

and the punishment for embezzlement is small enough, i.e.

$$0 \leq b \leq \frac{1}{2}(1 - \alpha),$$

there exists a pure-strategy (embezzlement) Nash equilibrium where at least one citizen pays her taxes and the governor embezzles one unit of public good, whenever he has an opportunity to do so.

This proposition stipulates that high punishment for tax evasion forces citizens to pay taxes. At the same time, a small enough punishment for embezzlement encourages the governor to steal one unit. For $z = 1$ (and same restriction on b as provided by Proposition 2 above) we have $(1l, 0h, L)$ and $(0h, 1l, L)$ as the PS(embezzlement)NE where only one of the citizens evades tax and the governor embezzles when the opportunity arises (i.e. when a tax-evading citizen is audited resulting in $X = 2$ for the governor to re-distribute). This result is very intuitive and similar results[20] exist in the literature which examine whether some form of accountability (may be, electoral) could discourage peculation.

Example 3. 'Efficient' public good provision: Assuming $\alpha = \frac{2}{3}$, $z = \frac{1}{2}$, $b = \frac{1}{2}$, we have $(1h, 1h, H)$ as the PSNE of the reduced normal form game, where both citizens

[18] There is extensive literature on peer-punishments to improve welfare and compliance for public good games; see, for instance, Fehr and Gächter (2002), Baldassarri and Grossman (2011), Andreoni and Gee (2012), Hilbe, Traulsen, Röhl, and Milinski (2014) and Grieco, Faillo, and Zarri (2017), among others.

[19] See Table 3 and Table 4 for details.

[20] See Welch and Hibbing (1997), Peters and Welch (1980), Reinikka and Svensson (2004), Fisman and Miguel (2007), Ferraz and Finan (2008), Barr, Lindelow, and Serneels (2009), Ferraz and Finan (2011), Bobonis, Cámara Fuertes, and Schwabe (2016), Weitz-Shapiro and Winters (2017), among others.

pay their taxes and guess correctly that the governor had two units for public good provision and the governor provides H level of public good. There can be multiple Nash equilibria in this scenario and we formally state this result in Proposition 3 below.

Proposition 3. *If the punishment for tax evasion is high enough,*

$$z \geq (1-\alpha),$$

and the punishment for embezzlement is high enough,

$$b \geq (1-\alpha),$$

then there exists a pure strategy (public good provision) Nash equilibrium where at least one citizen pays taxes and the governor re-distributes the entire public fund.

This proposition demonstrates that if both punishments for tax evasion and embezzlement are high enough, then every member benefits. For $z = 1-\alpha$ (and the same restriction on b as given by Proposition 3 above), we have $(0l, 1l, H)$, $(0h, 1l, H)$, $(1l, 0l, H)$ and $(1l, 0h, H)$ as the PS(public good provision)NEs of the game where only one of the citizens pay taxes (i.e. an asymmetry in the behaviour of the citizens[21]) and the governor is honest i.e. re-distributes two units of public good when the opportunity arises (if the tax-evading citizen is audited, governor has $X = 2$). To ensure an efficient public good provision, i.e. a situation where both citizens pay taxes and the governor redistributes the entire public fund, we impose a strict restriction on z (keeping the restriction on b same as above).

Corollary 1. *For $z > (1-\alpha)$, there exists a pure strategy ('efficient' pubic good provision) Nash equilibrium where both citizens pay their taxes and the governor re-distributes the entire public fund.*

We assume $\frac{1}{3} \leq \alpha \leq 1$ for efficiency, and given the restrictions on z and b from Proposition 3 and Corollary 1, we have $(1l, 1h, H)$, $(1h, 1l, H)$, $(1l, 1l, H)$ as the PS('efficient' public good provision)NEs of the game where both citizens pay taxes and the governor makes high two-unit, H, public good provision and citizens guess either l or h in this information set, which is out of the equilibrium path.

There is an extensive theoretical literature on optimal public good provision which looks at various (punishment) mechanisms[22] (see Groves and Ledyard (1977)

[21]See Erard and Feinstein (1994) and Gibson, Tanner, and Wagner (2013) for related literature.

[22]See Smith (1980) for an earlier experiment on a different type of (auction) mechanism for public good provision.

for details) which encourage individuals to make contributions towards the public fund. Falkinger (1995) and Andreoni and Bergstrom (1996) propose incentive schemes where the government should reward (via subsidies) or penalize (via additional taxes) deviations from mean contribution in order to increase efficiency. Some more recent experimental studies[23] try to test the validity of the theoretical results to find that some form of penalties does encourage contributions (or reduce tax evasion). Citizens' behaviour depends on the motivations, intentions and behaviour of the government. Empirical evidence suggests citizens are likely to evade taxes if they believe the government will not provide good service. Citizens will comply if the government reciprocates their trust (see Luttmer and Singhal (2014), Slemrod (2007)). Casaburi and Troiano (2016) provide evidence of a positive interaction between improved tax-payer monitoring systems and political incentives, i.e. there is increase in the re-election likelihood with introduction of better auditing technologies, especially in areas where the government is more efficient in providing public goods. One of the closely related work is by Litina and Palivos (2016), where they model an overlapping generation economy with two distinct groups of agents: private citizens and politicians in order to explain why countries fall into a vicious circle of tax evasion and political corruption.[24] They find two stable equilibria: one equilibrium is when there is low corruption and low tax evasion and the other one is when there is high corruption and high tax evasion.

4 Conclusion

We provide a simple unified model of tax evasion, embezzlement and public good provision and show the links between the three. Our model provides an extremely rich setting, where with the help of our four basic parameters we can describe any possible situation. The amplitude of this result enables us to extend the model in various directions (empirical, experimental and theoretical). The model and our equilibrium predictions can be tested in a laboratory experimental setup. In addition to this, the model can be tested in a field with support of some real data. One can also think of how the equilibrium behaviour of the players will change when the model is considered in a repeated setting. We postpone these ideas for future work.

[23]See Alm, McClelland, and Schulze (1992), Chen and Plott (1996), Falkinger, Fehr, Gächter, and Winter-Ember (2000) , Bracht, Figuieres, and Ratto (2008), Uler (2011), Robbett (2016), among others.

[24]See DeBacker, Heim, and Tran (2015), Alm, Martinez-Vazquez, and McClellan (2016) for an interesting analysis on the relation between corporate tax evasion and corruption.

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A Appendix

Proof of Theorem 1.

For any profile to be a PSNE, strategies of players in the profile have to be mutual best responses. Consider the strategy profile $(1l, 1l, L)$. For C_1 (similarly, C_2), given that C_2 (C_1) and G play $1l$ and L, respectively, $1l$ has to be the best response of C_1 (C_2). Given that $C_{i=1,2}$ plays $1l$, L has to be the best response of G. That is, for $C_{i=1,2}$, we have, the following:

$$\begin{aligned} Eu_{C_i}(1l, 1l, L) &\geq Eu_{C_i}(1h, 1l, L) \\ \implies -1 + \alpha - \frac{1}{2}c &\geq -1 + \alpha \\ \implies c &\leq 0; \end{aligned}$$

$$\begin{aligned} Eu_{C_i}(1l, 1l, L) &\geq Eu_{C_i}(0h, 1l, L) \\ \implies -1 + \alpha - \frac{1}{2}c &\geq -\frac{1}{2} + \alpha - \frac{1}{2}z \\ \implies z &\geq 1 + c;^{25} \end{aligned}$$

and for G, we have:

$$\begin{aligned} Eu_G(1l, 1l, L) &\geq Eu_G(1l, 1l, H) \\ \implies 1 - b + \alpha &\geq 2\alpha \\ \implies b &\leq 1 - \alpha. \end{aligned}$$

From the inequalities above, we have $z \geq 1$, $c = 0$ and $b \leq 1 - \alpha$ as the conditions for the strategy profile $(1l, 1l, L)$ to be a PSNE. Analogously, we can derive the conditions on parameters z, b, c, α required for the remaining 31 strategy profiles to be PSNE for the reduced normal form game. In the interest of space and to avoid repetition, we do not include the proofs here but a summary of the conditions have been provided in Table 4. ■

[25] Note that given this inequality, we also have $Eu_{C_i}(1l, 1l, L) \geq Eu_{C_i}(0l, 1l, L)$.